UNIVERSITI PUTRA MALAYSIA

DETERMINATION OF HEAT TRANSFER COEFFICIENT AND QUALITY CHARACTERISTICS OF PASTEURISED PINK GUAVA (PSIDIUM GUAJAVA L., VARIETY BEAUMONT-30) JUICE DRINK WITH DIFFERENT BRIX

ZAINAL BIN SAMICHO

FEP 2001 1

DETERMINATION OF HEAT TRANSFER COEFFICIENT AND QUALITY CHARACTERISTICS OF PASTEURISED PINK GUAVA (*PSIDIUM GUAJAVA* L., VARIETY BEAUMONT-30) JUICE DRINK WITH DIFFERENT BRIX

By

ZAINAL BIN SAMICHO

Thesis Submitted in Fulfilment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Food Science and Biotechnology Universiti Putra Malaysia

September 2001

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

DETERMINATION OF HEAT TRANSFER COEFFICIENT AND QUALITY CHARACTERISTICS OF PASTEURISED PINK GUAVA (*PSIDIUM GUAJAVA* L., VARIETY BEAUMONT-30) JUICE DRINK WITH DIFFERENT BRIX

By

ZAINAL BIN SAMICHO

September 2001

Chairman: Associate Professor Dr. Russly Abd. Rahman

Faculty: Food Science and Biotechnology

Heat transfer plays a key role in the production of good quality pasteurised fruit juice drink. Knowledge of heat transfer during the pasteurisation process and the necessity of analysing the data quantitatively have become increasingly important in modern pasteurisation technology. The importance of heat transfer in the production of comfort heating was readily apparent. Heat transfer was not only important in designing the pasteurisation equipment but it was also important in the optimisation of the pasteurisation process for the production of high quality fruit juice drink. Several properties of fruit juice drink such as the microbial, enzyme and sucrose contents, cloud stability and ascorbic acid are greatly affected by heat transfer during pasteurisation.

The effect of various operating conditions of pasteurisation on the thermophysical properties (density, thermal conductivity, specific heat capacity,

consistency coefficient and flow behaviour index) of pink guava juice drink was investigated. Pink guava juice drink with different total soluble solids (9^0Brix and 11^0Brix) at pH 3.7 with an average particle size of 0.355 mm was used in this study. The pink guava (*Psidium guajava* L.) variety Beaumont: B-30 was supplied by the Golden Hope Plantation, Kulai, Johore, Malaysia. All pasteurisation experiments were performed by using a pilot plant heat exchanger (APV tubular pasteuriser), which was operated at different temperatures and mass flow rates or holding times. During storage at 5^0C and at room temperature, the quality of the juice drink pasteurised at different conditions, measured as pectinesterase activity, cloud stability, microbial population, sugar and ascorbic acid contents, was analysed.

The data gathered from this study were used to develop models which could be employed to describe the variation in the physical properties of pink guava juice drink with different total soluble solids as a function of the pasteurisation operating temperature. The heat transfer coefficient models which related to mass flow rate for laminar flow were also developed. Such models are useful for the simulation process, so that the rate of heat transfer to the juice drink and the quality of the pasteurised juice drink at different pasteurisation operating conditions could be predicted. The models could also be used in designing the pasteurisation set up and the optimisation of the pasteurisation process with a great reduction in the number of experimental runs to be carried out.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PENENTUAN ANGKALI PEMINDAHAN HABA DAN CIRI-CIRI KUALITI TERPASTEUR JUS MINUMAN JAMBU MERAH (*PSIDIUM GUAJAVA* L., JENIS BEAUMONT-30) YANG BERBEZA BRIX

Oleh

ZAINAL BIN SAMICHO

September 2001

Pengerusi: Professor Madya Dr. Russly Abdul Rahman

Fakulti: Sains Makanan dan Bioteknologi

Pemindahan haba memainkan peranan penting dalam penghasilan jus minuman buah-buahan terpasteur yang berkualiti baik. Pengetahuan berkaitan dengan pemindahan haba semasa proses pempasteuran dan keperluan menganalisis data secara kuantitatif menjadi bertambah penting dalam teknologi pempasteuran moden. Kepentingan pemindahan haba dalam membantu proses pemanasan telah tersedia maklum. Pemindahan haba bukan sahaja penting dalam merekabentuk peralatan pempasteuran tetapi juga untuk mendapatkan proses pempasteuran yang optimis bagi tujuan menghasilkan jus minuman buah-buahan yang berkualiti tinggi. Beberapa ciri jus minuman buah-buahan seperti kandungan mikrob, enzim dan sukrosa, kestabilan keruh dan asid askorbik amat mudah dipengaruhi oleh pemindahan haba semasa pempasteuran.

Kajian berkaitan dengan kesan daripada pelbagai keadaan pempasteuran terhadap ciri-ciri fizikal haba (ketumpatan, keberaliran haba, muatan haba tentu, pekali kekonsistenan dan indek kelakuan aliran) jus minuman jambu merah telah dilakukan. Jus minuman jambu merah yang berlainan jumlah pepejal larut (9^{o}Brix dan 11^{o}Brix), pH 3.7 dan majoriti saiz zarah 0.355 mm, telah digunakan dalam kajian ini. Jambu merah (*Psidium guajava* L.) jenis Beaumont: B-30 didapati dari Estet Golden Hope, Kulai, Johor, Malaysia. Kesemua ujikaji pempasteuran dijalankan dengan menggunakan loji pandu penukar haba (alat pempasteuran tiub APV) yang beroperasi pada suhu dan kadar aliran jisim yang berlainan atau masa menahan. Semasa penstoran pada 5^{o}C dan suhu bilik, kualiti jus minuman yang dipasteurkan pada keadaan berlainan telah dianalisis dari segi aktiviti enzim pectinesterase, kestabilan keruh, populasi mikrob, kandungan gula dan kandungan asid askorbik.

Himpunan data daripada kajian ini telah digunakan untuk menghasilkan model-model yang boleh menerangkan perubahan ciri-ciri fizikal jus minuman jambu merah berlainan jumlah pepejal larut sebagai fungsi suhu operasi pempasteuran. Model-model pekali pemindahan haba berkaitan dengan kadar aliran jisim bagi aliran lamina telah dapat dihasilkan juga. Model-model tersebut amat berguna untuk perlakuan proses dan dengan itu kadar pemindahan haba kepada jus minuman dan kualiti jus minuman pasteur pada keadaan operasi pempasteuran yang berbeza boleh diramalkan. Model-model tersebut juga boleh digunakan untuk merekabentuk alat pempasteuran yang hendak dicipta juga dapat menghasilkan satu kaedah yang lebih optimis dalam proses pempasteuran dan dengan itu boleh mengurangkan banyak ujikaji cubaan.

ACKNOWLEDGEMENTS

In the name of Allah, the Most Beneficient, the Most Merciful

I thank Associate Professor Dr. Russly Abdul Rahman, Associate Professor Dr. Arbakariya Ariff and Associate Professor Dr. Nazamid Saari for their encouragement and patience in supervising this work.

I am grateful to the Faculty of Food Science and Biotechnology for permission to use all of the facilities which made my project successful and meaningful.

I am indebted to Universiti Teknologi MARA, Selangor, Malaysia for providing the scholarship which made my Ph.D programme in Universiti Putra Malaysia possible.

I am deeply grateful to my late father, to my mother and to my family for their constant encouragement, advice and moral support.

And last, but not least, I would like to extend my thanks to everyone who has directly or indirectly, contributed towards the completion of this thesis such as Associate Professor Dr. Salmah Yusuf, Mr. Dzulkifli Mat Hashim, Mr. Mustafa Marzuki, Mr. Amran Suratman, Mr. Azhar Mohd. Noor, Mr. Razali Othman, Mr. Rusli Aslim and others.

I certify that an Examination Committee met on 7th September 2001 to conduct the final examination of Zainal bin Samicho on his Doctor of Philosophy thesis entitled "Determination of Heat Transfer Coefficient and Quality Characteristics of Pasteurised Pink Guava (*Psidium Guajava* L., Variety Beaumont-30) Juice Drink with Different Brix" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree.Members of the Examination Committee are as follows:

Gulam Rusul Rahmat Ali, Ph.D.
Professor,
Faculty of Food Science and Biotechnology
Universiti Putra Malaysia
(Chairman)

Russly Abd. Rahman, Ph.D.
Associate Professor
Faculty of Food Science and Biotechnology
Universiti Putra Malaysia
(Member)

Arbakariya Ariff, Ph.D.
Associate Professor
Faculty of Food Science and Biotechnology
Universiti Putra Malaysia
(Member)

Nazamid Saari, Ph.D.
Associate Professor
Faculty of Food Science and Biotechnology
Universiti Putra Malaysia
(Member)

Romeo Toledo, Ph.D.
Professor
Department of Food Science and Technology
University of Georgia
Athens, U.S.A.
(Independent Examiner)

MOHD. GHAZALI MOHAYIDIN, Ph.D.,
Professor/ Deputy Dean of Graduate School,
Universiti Putra Malaysia

Date: 30 OCT 2001

This thesis submitted to Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy.

AINI IDERIS, Ph. D.
Professor,
Dean of Graduate School,
Universiti Putra Malaysia

Date: 13 DEC 2001

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or currently submitted for any other degree at UPM or other institutions.

ZAINAL BIN SAMICHO

Date: 29/10/2001

TABLE OF CONTENTS

		Page
ABSTRACT		2
ABSTRAK		4
ACKNOWLEDGEMENTS		7
APPROVAL SHEETS		8
DECLARATION FORM		10
LIST OF TABLES		16
LIST OF FIGURES		19
LIST OF PLATES		21
LIST OF ABBREVIATIONS		23
CHAPTER		
I	**GENERAL INTRODUCTION**	27
II	**LITERATURE REVIEW**	33
	Guava	33
	Biochemical Compositions of Guava	34
	Pectinesterase	34
	Mechanism for Pectinesterase Activity	37
	Optimum pH for Pectinesterase Activity	39
	Optimum pH and Temperature for Pectinesterase Activity	41
	Importance of Pectinesterase on Cloud Stability	42
	Fruit Juice Cloud	44
	Clarification of Juice	47
	Stabilisation of Cloud Juice	49
	Heat Treatment	55
	Pasteurisation	55
	Thermostability of Pectinesterase	59
	Effect of Heating	62
	Vitamin	62
	Physical and Chemical Changes	63
	Colour and Flavour	64
	Rheological Properties of Fluid Foods	65
	Classification of Fluid Foods	65
	Rheological Models for Viscous Foods	68
	Models for Time-Independent Behaviour	68
	Measurement of Flow Properties of Fluid Foods	70
	Rheology of Fluid and Food Processing	71

Heart Transfer 71
Heat Transfer to Foods Flowing in Tubes 71
Heat transfer to Pseudoplastic Fluid in Laminar Flow 73
Tubular Heat Exchanger 76
Application of Tubular Heat Exchanger 78
Storage Stability of Fruit Juice Drink 79
Cloud Loss 80
Microbial Spoilage 80
Sugar Fermentation 82
Ascorbic Acid Degradation 83

III THERMOPHYSICAL PROPERTIES OF PSEUDOPLASTIC CHARACTERISTICS OF PINK GUAVA JUICE DRINK AT TWO LEVELS OF TOTAL SOLUBLE SOLIDS 85
Introduction 85
Materials and Methods 86
Materials 86
Sample Preparation 87
Pseudoplastic Characteristic: Flow Behaviour Index and Consistency Coefficient 88
Density 89
Thermal Conductivity 89
Specific Heat Capacity 90
Results and Discussions 90
Effect of Temperature and Total Soluble Solids on Pseudoplastic Characteristic, Flow Behaviour Index and Consistency Coefficient 90
Effect of Temperature and Total Soluble Solids on Density... 98
Effect of Temperature and Total Soluble Solids on Thermal Conductivity 100
Effect of Temperature and Total Soluble Solids on Specific Heat Capacity 102
Conclusion 104

IV LAMINAR HEAT TRANSFER TO PINK GUAVA JUICE DRINK EXHIBITED PSEUDOPLASTIC BEHAVIOUR IN TUBULAR HEAT EXCHANGER 105
Introduction 105
Mass balance 106
Heat transfer 109
Materials and Methods 111
Materials 111
Sample Preparation 111
Specific Heat Capacity 112
Density 112

Viscosity, Flow Behaviour Index and
Consistency Coefficient 112
Heat Treatment of Juice Drink 113
Results and Discussion 116
Shear Rate 116
Characteristic of Juice Drink 117
Heat Transfer 120
Conclusion 124

V RELATIVE RESIDUE PECTINESTERASE ACTIVITY AND CLOUD LOSS OF PINK GUAVA JUICE DRINK PASTEURISED AT DIFFERENT HEAT QUANTITY 125
Introduction 125
Materials and Methods 128
Materials 128
Sample Preparation 128
Heat Treatment of Juice Drink 128
Determination of Pulp Content 129
Determination of PE Activity 130
Cloud Index Determination 130
Calcium Determination 131
Statistical Analysis 132
Results and Discussion 132
Effect of Pasteurisation Conditions on PE Activity 132
Effect of TSS on PE Activity 136
Effect of Storage Temperature on PE Activity 137
Effect of Pulp Content on PE Activity 138
Effect of Pasteurisation Conditions on Cloud Loss 138
Effect of TSS on Cloud Loss 141
Effect of Storage Temperature on Cloud Loss 142
Effect of Pulp Content on Cloud Loss 142
Effect of Calcium Content on Cloud Loss 143
Relationship Between PE Activity and Cloud Loss 144
Conclusion 147

VI EEFECT OF DIFFERENT HEAT QUANTITY ON MICROORGANISM POPULATION, SUGAR AND ASCORBIC ACID CONTENT IN PINK GUAVA JUICE DRINK DURING STORAGE 148
Introduction 148
Materials and Methods 153
Materials 153
Sample Preparation 153
Heat Treatment of Juice Drink 153
Microbiological Analysis 154
Determination of Sugar 155

Preparation of Sample for HPLC 156
Preparation of Standard 156
Quantification of Sugar 156
Determination of Ascorbic Acid 157
Statistical Analysis 158
Results and Discussions 158
Mesophilic 158
Yeast and Mould 161
Lactic acid bacteria 164
Properties Affecting Sucrose Concentration During
Storage of Pasteurised Pink Guava Juice Drink 169
Effect of Heat Quantity on Sucrose 170
Effect of Total Soluble Solids on Sucrose 170
Effect of Storage Temperature on Sucrose 173
Properties Affecting Glucose Concentration During
Storage of Pasteurised Pink Guava Juice Drink 173
Effect of Heat Quantity on Glucose 176
Effect of Total Soluble Solids on Glucose 176
Effect of Storage Temperature on Glucose 177
Properties Affecting Fructose Concentration During
Storage of Pasteurised Pink Guava Juice Drink 177
Effect of Heat Quantity on Fructose 178
Effect of Total Soluble Solids on Fructose 178
Effect of Storage Temperature on Fructose 181
Effect of Heat Quantity on Ascorbic Acid 182
Effect of Total Soluble Solids on Ascorbic Acid 185
Effect of Storage Temperature on Ascorbic Acid 186
Conclusion 186

VII CONCLUSION AND RECOMMENDATION FOR FUTURE WORK 190

BIBLIOGRAPHY 193

APPENDICES 205

BIOGRAPHICAL SKETCH 230

APPENDICES

Page

Appendix A: Total Hectarage of Guava in Peninsular Malaysia 205

Appendix B: Chemical Composition of Fruit Juices 206

Appendix C: Types and Characteristics of Guava 207

Appendix D: Nutrient Composition of Guava 211

Appendix E: Characteristics of Guavas for Juice Processing 212

Appendix F: Amount and Value of Guava Exported 214

Appendix G: Malaysia's 1991 Export and Total Value for Fresh and Processed Fruits 215

Appendix H: Biochemical Changes in Guava (cv Baladia) During Ripening 216

Appendix I: Plates 217

Appendix J: Standard Curve for Sugar 229

LIST OF TABLES

Table	Page
1: The Presence of Pectinesterase in Some Fruits	35
2: Distribution of Pectinolytic Enzymes in Some Microorganisms	35
3: The Optimum pH for Pectinesterase Activity in Some Microorganisms and Fruits	40
4: Optimum pH and Temperature of Some Fruits and Microbial Pectinesterase	42
5: Composition of Orange Juice Cloud	47
6: Effect of Heat Treatment on the Cloud Retention in Shamuti (Jaffa) Orange Juice	50
7: Influence of Calcium Ions and pH on the Retention of Cloud Particles Subjected to PE Action in Shamuti(Jaffa) Orange Juice	51
8: Pectinesterase (In)activators and Inhibitors	52
9: Effect of Added Essential Oil on Cloud Retention in Shamuti(Jaffa) Orange Juice	55
10: Enzyme Related to Food Quality and Inactivation of Pectinesterase	56
11: Flash Pasteurization Conditions for Fruit Juices	58
12: The Thermostability of Fruit Juices	61
13: The Effect of Sorbic Acid on Discoloration and Off-flavour of Guava Beverage (*Allahabad Safeda*) During Storage	65
14: Newtonian and Pseudoplastic Foods	68
15: Range of Experiment Conditions of Two Fluid Foods (CMC and Tomato Juice)	75
16: Power Law Equations for Different Temperatures and Total Soluble Solids	94
17: Equations of Thermophysical Properties for Different Total Soluble Solids	94

18: Shear Rate of Juice Drink Flowing in the Heating Section Tube During Pasteurisation at 75°C 116

19: Shear Rate of Juice Drink Flowing in the Heating Section Tube During Pasteurisation at 85°C 117

20: Characteristic of Juice Drink Flowing in the Heating Section Tube During Pasteurisation at 75°C 118

21: Characteristic of Juice Drink Flowing in the Heating Section Tube During Pasteurisation at 85°C 118

22: Summary of Parameter Characteristics of the Heat Transfer During Pasteurisation of Pink Guava Juice Drink at 75°C 121

23: Summary of Parameter Characteristics of the Heat Transfer During Pasteurisation of Pink Guava Juice Drink at 85°C 122

24: PE Activity During Storage of Pink Guava Juice Drink with TSS of 9°Brix which was Pasteurised at 75°C/12.9 sec or Heat Quantity = Q_1 and 85°C/12.1 sec or Heat Quantity = Q_3 133

25: PE Activity During Storage of Pink Guava Juice Drink with TSS of 11°Brix which was Pasteurised at 75°C/16.5 sec or Heat Quantity = Q_2 and 85°C/15.0 sec or Heat Quantity = Q_4 133

26: Cloud of Pink Guava Juice Drink TSS at 9°Brix Before Pasteurisation and During Storage, After Treatment by Different Heat Quantity 139

27: Cloud of Pink Guava Juice Drink TSS at 11°Brix Before Pasteurisation and During Storage, After Treatment by Different Heat Quantity 139

28: Concentrations of Calcium 143

29: Sucrose Content During Storage of Pink Guava Juice Drink with TSS of 9°Brix which was Pasteurised at 75°C/12.9 sec or Heat Quantity = Q_1 and 85°C/12.1 sec or Heat Quantity = Q_3 172

30: Sucrose Content During Storage of Pink Guava Juice Drink with TSS of 11°Brix which was Pasteurised at 75°C/16.5 sec or Heat Quantity = Q_2 and 85°C/15.0 sec or Heat Quantity = Q_4 172

31: Glucose Content During Storage of Pink Guava Juice Drink with TSS of 9°Brix which was Pasteurised at 75°C/12.9 sec or Heat Quantity = Q_1 and 85°C/12.1 sec or Heat Quantity = Q_3 175

32: Glucose Content During Storage of Pink Guava Juice Drink with TSS of 11°Brix which was Pasteurised at 75°C/16.5 sec or Heat Quantity = Q_2 and 85°C/15.0 sec or Heat Quantity = Q_4 175

33: Fructose Content During Storage of Pink Guava Juice Drink with TSS of 9°Brix which was Pasteurised at 75°C/12.9 sec or Heat Quantity = Q_1 and 85°C/12.1 sec or Heat Quantity = Q_3 180

34: Fructose Content During Storage of Pink Guava Juice Drink with TSS of 11°Brix which was Pasteurised at 75°C/16.5 sec or Heat Quantity = Q_2 and 85°C/15.0 sec or Heat Quantity = Q_4 180

35: Profile of Ascorbic Acid Content in Pink Guava Juice Drink with TSS Value of 9°Brix which was Pasteurised at 75°C/12.9 sec (Heat Quantity = Q_1) and 85°C/12.1 sec (Heat Quantity = Q_3) During Storage 183

36: Profile of Ascorbic Acid Content in Pink Guava Juice Drink with TSS Value of 11°Brix which was Pasteurised at 75°C/126.5 sec (Heat Quantity = Q_2) and 85°C/125.0 sec (Heat Quantity = Q_4) During Storage 183

LIST OF FIGURES

Figure	Page
1: Mode of Action of Pectinase	38
2: Reaction Mediated by Pectin Methylesterase	46
3: Theory of Orange Juice Cloud Loss Via Enzyme Action	48
4: Newtonian and Time-independent Non-Newtonian Fluids	67
5: RelationshiBetween Shear Stress and Shear Rate for Juice Drink with TSS at 9°Brix	92
6: Relationship Between Shear Stress and Shear Rate for Juice Drink with TSS at 11°Brix	93
7: Arrhenius Plots Showing the Effect of Temperature on the Flow Behaviour Index of Pink Guava Juice Drink	95
8: Arrhenius Plots Showing the Effect of Temperature on the Consistency Coefficient of Pink Guava Juice Drink	96
9: Effect of Temperature on Density of the Pink Guava Juice Drink	99
10: Effect of Temperature on Thermal Conductivity of the Pink Guava Juice Drink	101
11: Effect of Temperature on Specific Heat Capacity of th e Pink Guava Juice Drink	103
12: Side View of Several Sections of the Tubular Heat-exchanger	108
13: Experimental Equipment	114
14: Viscosity Versus Shear Rate for Juice Drinks with TSS at 9°Brix and TSS at 11°Brix at Inlet Temperature 27°C	119
15: Shear Stress/Shear Rate Relationship for Juice Drinks with TSS at 9°Brix and TSS at 11°Brix at Inlet Temperature 27°C	123
16: Relative Residue PE Activity During Storage for Pink Guava Juice Drinks of TSS at 9°Brix and TSS at 11°Brix which were Pasteurised with Different Heat Quantity	134

17: Cloud Loss During Storage for Pink Guava Juice Drinks of TSS at 9°Brix and TSS at 11°Brix which were Pasteurised with Different Heat Quantity 140

18: The Relationship Between Residue PE Activity and Cloud Loss During Storage at 5°C for Pink Guava Juice Drink which was Pasteurised at Different Heat Quantity 146

19: Mesophilic Population During Storage for Pink Guava Juice Drinks of TSS at 9°Brix and TSS at 11°Brix which were Pasteurised with Different Heat Quantity 160

20: Yeast and Mould Population During Storage for Pink Guava Drinks Juice of TS at 9°Brix and TSS at 11°Brix which were Pasteurised with Different Heat Quantity 163

21: Lactic acid bacteria Population During Storage for Pink Guava Juice Drinks of TSS at 9°Brix and TSS at 11°Brix which were Pasteurised with Different Heat Quantity 163

22: The Change of pH During Storage of Pink Guava Juice Drink which were Pasteurised with Different Heat Quantity 165

23: Sucrose Degradation During Storage for Pink Guava Juice Drinks of TSS at 9°Brix and TSS at 11°Brix which were Pasteurised with Different Heat Quantity 171

24: Glucose Accumulation During Storage for Pink Guava Juice Drinks of TSS at 9°Brix and TSS at 11°Brix which were Pasteurised with Different Heat Quantity 174

25: Fructose Accumulation During Storage for Pink Guava Juice Drinks of TSS at 9°Brix and TSS at 11°Brix which were Pasteurised with Different Heat Quantity 179

26: Ascorbic Acid Loss During Storage for Pink Guava Juice Drinks of TSS at 9°Brix and TSS at 11°Brix which were Pasteurised with Different Heat Quantity 184

LIST OF PLATES

Plate		Page
1.	Pink Guava (*Psidium guajava* L.) Variety Beaumont-30 Left: 80% Ripe, Right: Fully Ripe	217
2.	Washing of Pink Guava Fruits	217
3.	Pink Guava Fruits (halved)	218
4.	Pink Guava Fruits During Crushing by the Coconut Grinder ...	218
5.	Grinding and Separating of Crushed Pink Guava Fruits Left Pail: Puree, Right Pail: Waste	219
6.	The APV Pilot Plant Tubular Heat Exchanger	219
7.	Bottling of Pasteurised Pink Guava Puree	220
8.	HDPE Bottles of Pasteurised Pink Guava Puree in Freezer	220
9.	Defrosting of Pasteurised Pink Guava Puree in HDPE Bottles	221
10.	Mixing of Puree with Water and Sugar	222
11.	Centrifuge (Model Kabato)	223
12.	Brookfield Rheometer (Model DV III)	223
13.	Differential Scanning Calorimetry (DSC 7)	224
14.	Pouring of Pink Guava Juice Drink into the Mixing Tank of the APV Tubular Heat Exchanger	224
15.	Pink Guava Juice Drink in HDPE Bottles at 0 day	225
16.	Pink Guava Juice Drink in HDPE Bottles Kept in 5°C After 4 Weeks Storage Times	225
17.	Pink Guava Juice Drink in HDPE Bottles Kept in RT After 1 Week Storage Times	226

18. Auto Titrator (VIT Video Titrator) 226

19. UV- Visible Spectrophotometer
(Model Shimadzu UV-1601PC) 227

20. Atomic Absorption Spectrophotometer
(Model Perkin-Elmer 5100PC) 227

21. HPLC (Model Waters 410 Refractive Index Detector) 228

LIST OF ABBREVIATIONS

AFHP	ASEAN Food Habits Project
FAFR	Food Act Food Regulation
MAFF	Ministry of Agriculture, Fisheries and Food
MARDI	Malaysian Agricultural Research and Development Institute
PE	Pectinesterase
PG	Polygalacturonase
PMG	Polymethylgalacturonase (pectin hydrolase)
PMGL	Polymethylgalacturonate lyase (pectin lyase)
PGL	Polygalacturonate lyase (pectate or pectic acid lyase)
PPO	Polyphenoloxidase
HDPE	High density polyethylene
NaOH	Sodium hydroxide
RT	Room temperature
n, n_H	Flow behavior index
K, K_H	Consistency coefficient (Pa s^n)
τ	Shear stress (N m^{-2})
τ_o	Yield stress (N m^{-2})
γ or S	Shear rate (s^{-1})
ρ	Density (g ml^{-1})
C_p	Specific heat capacity (J kg^{-1} $^oC^{-1}$)
k	Thermal conductivity (J m^{-1} s^{-1} $^oC^{-1}$)

T	Temperature (°C)
T'	Temperature (Kelvin)
α	Thermal diffusivity of the fluid (m^2s^{-1})
p	Moisture content (kg moisture/kg of juice drink)
TSS	Total soluble solid
a, b, γ	Constant
F	Constant (m^2N^{-1})
A'	Constant (s^{-1})
n_∞	Frequency factors
K_∞	Frequency factors (Pa s^n)
E_{ak}	Activation energy (J mol^{-1})
R	Gas constant (8.314 J K^{-1} mol^{-1})
h_m	Mean heat transfer coefficient
ω	Mass flow of the juice drink
D	Diameter
ν	Velocity of juice drink
r	Radius
A	Area
V	Volume of juice drink
μ	Viscosity of juice drink
Re	Reynolds number
Q	Total heat transfer
ΔT	Temperature different between inlet temperature and heating temperature